SCS STUDY REPORT - VOLUME 6

SPACE STATION
SIMULATION COMPUTER SYSTEM (SCS) STUDY
for
NASA/MSFC

STUDY ISSUES REPORT

TRW-SCS-89-T1

31 October, 1989

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National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, AL 35812

Attn: Mr. M. Naumcheff/EL12

Subject: Contract No. NAS8-37745/P00002
Final Technical Report
Simulation Computer System for Space Station Program

In accordance with the requirements of the subject contract, the final technical report titled SCS Study Report, consisting of six volumes is herewith submitted and distributed as shown.

TRW Inc.
Defense Systems Group

V. O'L. Bain
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Huntsville Operations
System Development Division

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SPACE STATION SIMULATION COMPUTER SYSTEM (SCS) STUDY

STUDY ISSUES REPORT

SCS SCS

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SCS SCS

CDRL: TRW-SCS-89-T1

31 October, 1989

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INTRODUCTION

The Simulation Computer System (SCS) is the computer hardware, software, and workstations that will support the Payload Training Complex (PTC) at MSFC. The PTC will train the Space Station payload specialists and mission specialists to operate the wide variety of experiments that will be on-board the Freedom Space Station

This Simulation Computer System (SCS) Study Issues Report summarizes the analysis and study done as Task 1- Identify and Analyze SCS Study Issues - of the SCS Study contract . This work was performed over the first three months of the SCS Study, which began in August of 1988.

First, issues were identified from all sources. These included the NASA SOW, the TRW proposal, and working groups which focused the experience of NASA and the contractor team performing the study - TRW, Essex, and Grumman. The final list is shown in Figure Issues 1, and is organized into training related issues, and SCS associated development issues. To begin the analysis of the issues, a list of all the functions for which the SCS could be used was created, i.e. when the computer is turned on, what will it be doing. Analysis was continued by creating an operational functions matrix of SCS users vs. SCS functions (Figure Issues 2) to insure all the functions considered were valid, and to aid in identification of users as the analysis progressed. The functions will form the basis for the requirements, which are currently being developed under Task 3 of the SCS Study.

To ensure that all relevant issues are identified, and as an aid to beginning analysis of all the issues, a matrix of the issues vs. functions (Figure Issues 3a &3b) was created. Filling in this matrix gave the study team an indication of the breadth - issues that affected many functions - and the depth - issues that had a large effect , but on only a few functions- of all the issues to be further analyzed.

A different and important view and analysis of the issues was performed by creating the cost factor vs. SCS issue matrix (Figure Issues 4a & 4b). This matrix shows which issues have big, medium, or small potential impact on the cost of building and operating the SCS system. Thus, this matrix is meant as a guide to emphasis and detail of analysis for each issue.

An issues form was created to capture the details of the analysis being performed, and this form evolved as the analysis proceeded. The final version of this form is shown as Figure Issues 5. Following this are the completed forms for each of the issues. The data on these forms is the result of the matrices above, study, thought, graphic analysis, and numerous SCS working group meetings to discuss and lay the SCS ground rules and assumptions.

The assumptions listed on the issue forms are duplicated in the issues appendix after the completed forms so that all SCS assumptions can be easily accessed and assessed.

Issues requiring further analysis, as indicated on the form under recommendations, need further analysis to aid the study team in writing a good first cut requirement. Many of the issues will be further analyzed as part of SCS Study Task 4 - Develop SCS Conceptual Designs.

MSFC is responsible for approving this SCS Issues Report. TRW will assume MSFC approval of this report in the absence of any specific MSFC disapproval within 30 days of delivery of this report to MSFC. However, it is TRW's current intention to include this report as a chapter in the SCS Final Study Report, and thus any comments or additions that are relevant and important are solicited.

Training Related Issues

Further Study?	Issue Number & Title
Yes	T-1. Scope of Payload Crew Training in PTC
No	T-2. Scope of Ground Operations Personnel Training in PTC
Yes	T-3. Scope of OMS Training in PTC
Yes	T-4. Scope of Integrated Core Subsystem Training in PTC
No	T-5. Fidelity of SS Payload Subsystems Simulations
No	T-6. Fidelity of SS Experiment Simulations
No	T-7. Fidelity of SS Experiment to System Interfaces
No	T-8. Fidelity of SS Internal Data Flows Simulations
No	T-9. Fidelity of SS Downlink and Uplink
Yes	T-10. Fidelity of Element Control Workstation (ECWS)
No	T-11. Support for Training Multiple Missions Simultaneously
No	T-12. Support for Integrated Simulations with Other NASA Centers
Yes	T-13. Support for Interoperable (Remote Executions) Simulations
No	T-14. Requirements for SCS Interface with External Facilities
Yes	T-15. Requirements for PTC Payload Video Data
No	T-16. Requirements for Simulation Parameter Update Rate Requirements
No	T-17. Requirements for High Rate Data Requirements
No	T-18. Requirements for Virtual Instruments
No	T-19. Requirements for Simplified Simulator Operations Setup and Control
Yes	T-20. Support for Onboard Training

Associated Development Issues

Further Study?	Issue Number & Title
No	A-1. Utilization of SSE Capabilities
No	A-2. Techniques for Integrating and Maintaining PI-Provided Simulators
Yes	A-3. Techniques for Supporting late changes to simulators
No	A-4. Allowing Software Transportability between SCS and other centers
Yes	A-5. Techniques for Integrating Flight Hardware/Software with SCS Simulators
Yes	A-6. Flexibility for Allowing Advanced Technology Insertion
Yes	A-7. Implications of Simulation Development Cycle
Yes	A-8. Sizing Growth Potential in Capability/Capacity
No	A-9. Defining Telemetry Data Format and Calibration
Yes	A-10. Fidelity of DMS Interface
Yes	A-11. Definition of "No single point of failure"
No	A-12. Requirements for Interfaces with SOAN and SSIS
No	A-13. Requirements for Configuration Management of Simulation Software
Yes	A-14. Definition of GSE-Provided Services

Figure Issues 1. List of SCS Study Issues

FIGURE ISSUES 2. SCS OPERATIONAL FUNCTIONS VS USERS

SCS Operational Functions / Users	SCS Training Functions								Simulation Development Functions							Operations Evaluations				
	Perform Experiment Orientation	Perform CAI Individual Training	Perform Experiment Training (Nominal)	Perform Experiment Training (Malfunction)	Perform Crew Exp Integrated TL Training	Perform Crew/Cadre Ops Integrated Training	Perform USLAB Integrated Training	Perform Station Integrated Training	Support Simulation Requirements Analysis	Support Simulation Designs	Implement Simulators	Integrate/Test Simulators	Integrate Simulators with Flight H/W & S/W	Integrate Transported Simulators	Integrate Remote Interoperable Sims	Support OPS Concept Definition	Support Crew Procedure Development	Support Timeline Validation	Demonstrate/Evaluate SS Technologies	
Flight Crew																				
P/L Specialists	x	x	x	x	x	x	x	x												
P/L Operators	x	x	x	x	x	x	x	x												
Mission Specialists	x	x	x	x	x	x	x	x												
Station Operators	x							x												
Ground Support Crew																				
Payload OPS Director	x	x				x	x	x									x			
Ops Control Team	x				x	x	x	x												
Replan Team	x					x	x	x												
Data Mngt Team	x					x	x	x												
Science Users															x		x			
PI Teams						x	x	x												
Mission Scientist	x					x	x	x												
PTC Personnel																				
Simulation Developer	x								x	x	x	x	x	x	x		x			
Instructors	x	x	x	x	x	x	x	x	x	x					x					
PTC Operators						x	x	x					x	x	x					
Ops Planning Personnel																	x	x	x	x

FIGURE ISSUES 3a. SCS OPERATIONAL FUNCTIONS VS TRAINING ISSUES

Training Related Issues \ SCS Operational Functions	SCS Training Functions								Simulation Development Functions								Operations Evaluations			
	Perform Experiment Orientation	Perform CAI Individual Training	Perform Experiment Training (Nominal)	Perform Experiment Training (Malfunction)	Perform Crew Exp Integrated TL Training	Perform Crew/Cadre Ops Integrated Training	Perform USLAB Integrated Training	Perform Station Integrated Training	Support Simulation Requirements Analysis	Support Simulation Designs	Implement Simulators	Integrate/Test Simulators	Integrate Simulators with Flight H/W & S/W	Integrate Transported Simulators	Integrate Remote Interoperable Sims	Support OPS Concept Definition	Support Crew Procedure Development	Support Timeline Validation	Demonstrate/Evaluate SS Technologies
T-1 PL Crew Training	x	x	x	x	x	x	x	x							x				
T-2 Ground Ops Trng	x	x	x	x	x	x	x	x										x	
T-3 OMS Training					x	x	x	x											
T-4 Core Subsystem Trng								x											
T-5 PL Subsystems Sims					x	x	x	x									x		
T-6 Experiment Fidelity	x	x	x	x	x	x	x	x	x	x	x	x							
T-7 Exp/System I/F							x	x		x	x	x	x	x		x			x
T-8 Data Flow Fidelity						x	x	x		x		x						x	
T-9 Downlink and Uplink						x	x	x		x		x						x	
T-10 Fidelity of ECWS			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
T-11 Multiple Missions					x	x	x												
T-12 Integrated Sims							x	x											
T-13 Remote Sims			x	x										x	x				
T-14 I/F to Ext. Facility								x		x		x							
T-15 Payload Video Data			x	x	x	x	x	x	x	x	x	x	x				x		
T-16 Paramter Updates			x	x	x	x	x	x		x		x							
T-17 High Rate Data						x	x	x	x										
T-18 Virtual Instruments		x	x	x															
T-19 Simplified Setup			x	x	x	x	x	x											

FIGURE ISSUES 3b. SCS OPERATIONAL FUNCTIONS VS DEVELOPMENT ISSUES

SCS Development Issues \ SCS Operational Functions	SCS Training Functions								Simulation Development Functions							Operations Evaluations			
	Perform Experiment Orientation	Perform CAI Individual Training	Perform Experiment Training (Nominal)	Perform Experiment Training (Malfunction)	Perform Crew Exp Integrated TL Training	Perform Crew/Cadre Ops Integrated Training	Perform USLAB Integrated Training	Perform Station Integrated Training	Support Simulation Requirements Analysis	Support Simulation Designs	Implement Simulators	Integrate/Test Simulators	Integrate Simulators with Flight H/W & S/W	Integrate Transported Simulators	Integrate Remote Interoperable Sims	Support OPS Concept Definition	Support Crew Procedure Development	Support Timeline Validation	Demonstrate/Evaluate SS Technologies
A-1 Utilization of SSE								x	x	x	x	x	x	x	x				
A-2 PI-Provided Sims												x		x	x				
A-3 Simulator Changes									x	x	x	x	x	x	x				
A-4 SW Transportability								x		x	x			x					
A-5 Flight HW/SW									x	x	x	x	x						
A-6 Technology Insertion		x							x	x	x								
A-7 Development Cycle									x	x	x	x							
A-8 Growth Potential					x	x	x	x			x	x							
A-9 Telemetry Data						x	x	x	x	x	x	x	x						
A-10 DMS Interface			x	x	x	x	x	x		x	x	x	x						
A-11 No Single Failure						x	x	x											
A-12 SAIS/SSIS I/F									x	x	x				x				
A-13 CM												x							
A-14 GSE Services									x			x	x	x					

Figure Issues 4a. Cost Factors vs. Training Issues

Training Related Issues \ Cost Factors	Computer Hardware (Speed, Size, Quality)	Display HW (Speed, Size Resolution, Number)	COTS Software	Development (SE, Design, Code, I&T)	Operations and Maintenance	Training (Computer and Personnel Time
T-1 PL Crew Training	B	B	S	B	S	B
T-2 Ground Ops Trng	M	M		M	M	S
T-3 OMS Training	M			M	S	M
T-4 Core Subsystem Trng	S	S		S		M
T-5 PL Subsystems Sims	M	B		B		
T-6 Experiment Fidelity	M	B		B		B
T-7 Exp/System I/F	M	B		B		
T-8 Data Flow Fidelity	M	B		B		
T-9 Downlink and Uplink	M	B		B		B
T-10 Fidelity of ECWS	S	B	M	M	S	
T-11 Multiple Missions	B	B		B	B	B
T-12 Integrated Sims	S	S	S	M		B
T-13 Remote Sims	S			S		M
T-14 I/F to Ext. Facility	S	S		M		B
T-15 Payload Video Data	B	B		B	M	B
T-16 Paramter Updates	M	M	M	B	S	B
T-17 High Rate Data	M	M		M	S	M
T-18 Virtual Instruments	S	S	M	M	M	
T-19 Simplified Setup				M	B	B

Legend:

B = Big
M = Medium
S = Small

Matrix represents level of potential impact on cost of SCS

Figure Issues 4b. Cost Factors vs. Development Issues

Development Issues \ Cost Factors	Computer Hardware (Speed, Size, Quality)	Display HW (Speed, Size Resolution, Number)	COTS Software	Development (SE, Design, Code, I&T)	Operations and Maintenance	Training (Computer and Personnel Time
A-1 Utilization of SSE				M	M	
A-2 PI-Provided Sims				B	B	B
A-3 Simulator Changes				B	B	
A-4 SW Transportability				S	S	S
A-5 Flight HW/SW	M			B	B	B
A-6 Technology Insertion	S	S		M	B	B
A-7 Development Cycle	M	M			M	M
A-8 Growth Potential	S	S			B	B
A-9 Telemetry Data				M		S
A-10 DMS Interface	B	B		B		B
A-11 No Single Failure	B	M	M	M	B	B
A-12 SAIS/SSIS I/F	S	S		M		B
A-13 CM			S	B	B	B
A-14 GSE Services	B			B	M	B

Legend:

B = Big
M = Medium
S = Small

Matrix represents level of potential impact on cost of SCS

SCS Issue Identification

Issue Title:

Issue No: Report Version:

Scope of Potential Requirement

Assumptions

Brief summary and rationale

Training Viewpoint

SCS Development Viewpoint

Operations Evaluations Viewpoint

Recommendations

- o No additional study required. Derived SCS Requirements and Implications on SCS Design:
- o Additional study required. Define study subjects and type of required analysis, e.g.; trades, simulations, projections.

Related Issues:

Open Issues/Notes

Figure Issues 5. Blank SCS Issues Form

TRAINING ISSUES

SCS Issue Identification

Issue Title: Scope of Payload Crew Training in PTC

Issue No: T-1 Report Version: 4

Scope of Potential Requirement

The scope of payload crew training in the PTC could range from simple single experiment operations training in a nominal operations scenario to full consolidated experiment operations training responsibility including orientation, stand-alone experiment training for nominal and malfunctions scenarios, and full consolidated experiment training with all experiments from a given SS increment configuration operating as a consolidated payload with all elements of the SS. The scope of the training responsibility of the PTC and the resulting fidelity of experiment simulators and SS payload subsystem interfaces will be the major driver on the SCS requirements.

Assumptions

1. Primary responsibility of the PTC is to provide payload operations training including both nominal and contingency operations for flight and ground personnel.

2. Payload operations training will include experiment training, payload unique operations support systems training , and payload unique subsystems training.

3. The PTC/SCS will support all manned payload training for all payloads, including US Lab, Attached Payloads, ESA, and JEM.

Brief Summary and Rationale

Training Viewpoint

The PTC will provide experiment operations training to the flight payload crew beginning 12 months prior to launch. Training will consist of individual experiment operations and consolidated payload operations (at the payload level). Training at the PTC is expected to last about 9 months and will include three major phases: individual experiment operations, experiment operations consolidated with payload subsystems, and finally consolidated experiment training in the Element Trainers environment.

There will be 4 crew/increment and 1/2 of the crew will be exchanged each flight. Thus the PTC will not only have the responsibility of training on payload operations for a particular flight but also must provide experiment operations training for the preceding and the following increment configurations. For any given increment configuration there will be 6 crew participating in training on that configuration. One of the primary objectives of the PTC will be to support team building in payload operations to allow the crew to work efficiently as a team to accomplish consolidated payload operations.

The payload training process will follow a building block approach in which the trainee will start with single experiment nominal operations and proceed through tasks of increasing complexity. The primary training objective of the PTC will be to support consolidated experiment operations training building on experiment training provided by the PI. One of the major emphasis of the PTC will be consolidated operations which require crew intervention via SS workstations which interact with payloads. Candidate workstations include the Element Control Workstation (ECWS), the Life Sciences and Maintenance workstations, the Materials Processing and Life Sciences Gloveboxes, and the Command and Control workstations.

SCS Development Viewpoint

The scope of payload crew training will be one of the largest drivers in terms of load on the SCS. The associated load for development of the software, integration, test, maintenance, and configuration management will also be quite large, probably larger than the load for training. We need to have a good set of requirements and a good understanding of all of this to be able to properly size and design the SCS.

Operations Evaluations Viewpoint

SCS capabilities for the support of full consolidated experiment operations training should provide the required functions for the prototyping, development, evaluation, and verification of flight crew procedures. The simulations of the payload support systems (e.g. PMMS, Lab Support Equipment) and their interactions with the experiments should be simulated to a high level of fidelity to prevent the use of facility-related workarounds in procedure verification. The SCS will support testing of maintenance procedures for only those experiments which provide flight equivalent hardware to the PTC.

Recommendations

o Additional study required. Additional analysis of typical design reference mission payloads must be performed to determine maximum loading on the SCS at any given time to support payload training. Analysis will include classifying SS payloads into three levels of simulator complexity and then determining CPU sizing requirements based on experiment simulators that have been developed for the Spacelab training program in the PCTC. Additional study will determine the SCS load required to support training for Attached Payloads.

Open Issues/Notes

SCS Issue Identification

Issue Title: Scope of Ground Operations Personnel Training in PTC

Issue No: T-2 Report Version: 4

Scope of Potential Requirement

The scope of PTC support to ground operations personnel training could range from limited support to ground support operations training for selected POIC console positions involved in direct commanding to individual experiments to a complete simulation of all POIC functions including data transformation, etc. PTC support to ground operations training could be limited to just operations training for POIC console positions or could also include training responsibility for personnel in the User Operation Facilities (UOFs), the Discipline Operations Centers (DOCs), the Regional Operations Centers (ROCs), and the Engineering Support Center (ESC).

Assumptions

4. ESC training is assumed to not be a responsibility of the PTC. No unique interface between the ESC and the SCS is required, nor will the SCS simulators require any unique capabilities related to ESC training. The only support of the SCS to ESC training will be via the POIC during consolidated and/or integrated simulations.

5. Any PTC interfaces to UOFs, DOCs, or ROCs will be through the POIC. There will not be any direct data interfaces from the PTC to the UOFs, DOCs, or ROCs.

6. The POIC can support the processing of real time or simulated data streams simultaneously. This means the POIC can support training using simulated data from the PTC simultaneous with on going real time operations.

Brief Summary and Rationale

Training Viewpoint

The first utilization of the PTC will be to train Payload Operations Integration Center (POIC) controllers. The PTC must provide payload training for the US Lab, Pressurized Logistics, Node modules, and attached payloads. The PTC support to POIC cadre training will extend beyond the traditional support that the PCTC has provided to POCC training in integrated simulations. The PTC will provide the training for the POIC ground support staff both before the POIC is available for use and after it becomes fully operational and occupied. Specific POIC console trainers will be necessary at the PTC. These consoles could then be fed payload data via payload simulations in the SCS host environment.

The specific training load that POIC personnel will place on the PTC will depend on the individual POIC positions interfaces and responsibilities for payload operations. There will be seven cadre teams with 30 controllers per team. However, the relative amount of payload operations training needed by each position will vary greatly from position to position. In addition to the POIC training responsibilities, the PTC support for Space Station Control Center (SSCC), Field Support, and PTC staff training must also be considered in the SCS requirements

For POIC console training in the PTC, approximately 7 POIC consoles will be required. This is based on one console for a lead operations position and two consoles each for Operations Execution, Data Management, and Mission Planning functions. This configuration would allow for coordination between the control and planning functions within the operations teams to be accomplished or all seven consoles could be configured to support team training for the POIC disciplines. The data stream processing functions of the POIC will not have to be duplicated at the PTC, but some of the data support functions such as command processing, exception monitoring, special computation execution, and display support for the POIC consoles may be required at the PTC.

SCS Development Viewpoint

The scope of ground operations personnel training will be a significant factor in SCS, and life cycle vs development costs will be a factor in the final SCS requirements. There may be special requirements for development of telemetry streams, accepting commands from ground consoles, etc. that will be a significant delta in effort above that required to build the simulators for issue T-1.

Operations Evaluations Viewpoint

SCS capabilities for the support of POIC console training should provide the required functions for the development, evaluation, and verification of ground operations procedures and data bases. High fidelity simulations of the POIC commanding capabilities and payload responses are required for efficient and reliable procedure/data base checkout. Experience in using the Spacelab Software Development Facility (SDF) for the checkout of POCC command data bases has shown the need for realistic responses in the simulation facility to the ground commands. If the simulator does not behave like the actual system, then various test notations and workarounds must be employed to compensate.

Recommendations

o No additional study required. The SCS is required to support 7 POIC consoles for part task POIC position training. The SCS shall support full uplink command to the payloads from the POIC, and downlink of all payload bus data packets.

Related Issues: T-14

Open Issues/Notes

SCS Issue Identification

Issue Title: Scope of OMS Training in PTC

Issue No: T-3 Report Version: 3

Scope of Potential Requirement

Operations Management System (OMS) training in the PTC could range from no interface between the payload simulators to a full interface with OMS trainers at JSC via an Operations Management Application (OMA) node. On the minimum end of the OMS training level, payload operations training at the PTC could have no relationship to OMS. On the maximum end, all payload training at the PTC could be conducted in the OMS environment.

Assumptions

7. The OMS software functions will be provided as part of the DMS Kits. Therefore no special simulator development will be required for OMS training.

Brief Summary and Rationale

Training Viewpoint

The Operations Management System will include an Operations Management Application (OMA) node for on-board operations and an Operations Management Ground Application (OMGA) node to support ground operations. Under each of these systems there will potentially be unique Payload Management System functions that will relate to the experiment operations. The primary training responsibility of the PTC will be on unique payload management functions relating to the OMS.

SCS Development Viewpoint

Even with our assumption that OMS is provided, there will be some interface and integration effort required of the development team. However, the use of WP02 provided OMS and OMGA simulation or the real flight software seems to be the best way to go, rather than have the PTC develop simulations for these.

Operations Evaluations Viewpoint

Crew and ground procedures can be expected to be heavily oriented toward the use of payload OMA functions for payload operations. A high fidelity simulation (or the use of actual payload OMA flight software) will be required to support procedure development and verification.

Recommendations

o Additional study required. The loading impact to the SCS to support OMS training must be determined

Open Issues/Notes

The unique payload management functions that will be involved in the OMS must be determined and the potential load that this implies to the SCS must be determined.

SCS Issue Identification

Issue Title: Scope of Integrated Core Subsystem Training in PTC

Issue No: T-4 Report Version: 3

Scope of Potential Requirement

The scope of the PTC support to integrated core subsystem training could range from experiment operations training which is totally independent of SS core subsystem statuses to a fully integrated simulation environment in which there is a two way interface between experiment simulators and the SS core subsystems simulators either within the PTC or in the SSTF. With this two way interface the experiment simulators would receive subsystem status data and be responsive to these inputs and would provide experiment status back to the subsystem simulators which would represent the experiment load on the subsystems. These subsystem simulators would be responsive to the experiment load to provide realistic experiment load reactions to the subsystem controllers.

Assumptions

8. The PTC will not be responsible for any subsystems training. However, the PTC will utilize minimum subsystem interfaces as necessary to support payload training.

9. All software subsystem simulators utilized in the PTC will be provided by work package contractors via the SSE. Modifications of these will be required.

Brief Summary and Rationale

Training Viewpoint

In the Spacelab training environment, payload operations training has been conducted with minimal interaction between the experiment and subsystems simulators. Spacelab experiment simulators have utilized simple discrete status data from subsystem simulators but have not provided any load data back into the subsystem simulators that would be reflected in data that is provided to the subsystem controllers. This has proved to be adequate for crew and payload cadre operations training but may not be adequate for subsystem training. The responsibility of the PTC to support core subsystem training must be determined and the level of interface fidelity between the core subsystems and the experiment simulators that is required to provide adequate experiment operations training must be defined.

SCS Development Viewpoint

Since we are assuming no responsibility for subsystem training, there will be no SCS development load for subsystem training. However, there will be SCS requirements for interfaces to subsystem simulations, and there will be a load for

integration. If simulations run on the SCS host, this must be included in the sizing and timing.

Operations Evaluations Viewpoint

The use of subsystem simulations to support the payload simulators will provide adequate capabilities for the development and verification of purely experiment operations crew/ground procedures. The level of influence of the subsystems on the procedures must be evaluated. For example, if a part of a payload activation procedure requires the payload operator to access the LAB power system then the procedure cannot be verified in the PTC without a simulation of the LAB power system in excess of what is required to interface with the payload simulations. The evaluation of prototype experiments or new technologies may also require physical simulations of certain core subsystems such as thermal and power to provide needed flight-like services.

Recommendations

o Additional study required: Additional analysis is needed to determine the necessary level of interface between subsystems and experiments. Information needs to be obtained from the SSTF developer (Mitre) about anticipated interface between the subsystem and payload simulators. We also need to determine the execution rate of the subsystem simulators, specifically will some simulators have to execute at a rate greater than 1 Hz.

Open Issues/Notes

Reference Draft 1 of the OP14 Plan (D683-10135-1); "A preliminary survey indicates none of the common subsystems are required to support payload simulations interfaces".

SCS Issue Identification

Issue Title: Fidelity of SS Payload Subsystem Simulators

Issue No: T-5 Report Version: 2

Scope of Potential Requirement

The scope of Space Station subsystem simulators can range from very simplistic low fidelity simulators that only provide discrete interface status to experiment simulators to fully functional subsystem simulators which provide two way interface capability to experiment simulators with detail subsystem data such as Electrical Power Distribution System voltage levels, cooling system temperatures, etc. These higher fidelity subsystem simulators would provide subsystem control capability and also reflect experiment status inputs into the subsystem data parameters. The number and type of subsystems to be simulated is also a driver of the SCS requirements. The subsystems associated with the US Lab, Pressurized Logistics, and Node Modules must be included. Additionally, the PTC support to the international payload modules must be considered.

Assumptions

2. Payload operations training will include experiment training, payload unique operations support systems training , and payload unique subsystems training.

4. ESC training is assumed to not be a responsibility of the PTC. No unique interface between the ESC and the SCS is required, nor will the SCS simulators require any unique capabilities related to ESC training. The only support of the SCS to ESC training will be via the POIC during consolidated and/or integrated simulations.

Brief Summary and Rationale

Training Viewpoint

In the Spacelab program, relatively simple subsystem simulators have been utilized to support payload operations training. The major thrust of Spacelab PCTC training has been on experiment operations, and systems training has not been a major function. Spacelab systems training has been a JSC responsibility rather than the responsibility of MSFC. This will also be the case for Space Station training. Systems simulators will be developed for the WP01 elements under the Software Support Environment (SSE) for the purpose of testing flight software development. These software testing simulators may be simple command/response simulators that only serve to provide test scenarios for the software interfaces. However, it may be just as practical to develop dynamic systems simulators to test the flight software because the software interface to the systems may be so complex. If this is the case, then these simulators could be migrated into the PTC and modified for trainer use. SS payload operations will be largely built around various SS workstations such as the Element Control Workstation (ECWS), Life Sciences and Maintenance workstations, the

Materials Processing and Life Sciences Gloveboxes, and the Command and Control workstations. The SCS design must account for the anticipated utilization of SS subsystem simulators.

The OP14 Plan reference identifies the US Lab subsystems that will be required to interface to payload simulations in the PTC. These subsystems include:

Vacuum Vent System
Acceleration System
General Lab Support Facility
Preservation and Storage System
Maintenance Workstation/Lab Sciences workbench
Mass Energy Analysis (MEA) Subsystem
Process Materials Management Subsystem (PMMS)

In addition, elements of the Animal Specimen Transport System (ASTS), and the Inventory Management System may be required to support payload training.

SCS Development Viewpoint

If most of the payload subsystems were done in software, this would be a factor in the SCS. However, since current thinking indicates that most of these are simulations that will be done with physical things (not software) there is not much affect on the SCS. However, some of these, like the current PCTC instrument pointing system simulation, may be done in software. The fidelity and size of these software simulations would then have a significant effect on SCS loading and size.

Operations Evaluations Viewpoint

The operation of the payload support subsystems will be an integral part of overall payload operations. Therefore, it should be expected that many crew procedures will involve the use of these support systems either in a stand-alone mode or integrated with the operation of the individual experiments. The simulations of the LAB payload support subsystems must be adequate to support procedure verification. The requirement for payload support subsystems simulators of a higher fidelity than those available from the SSE is therefore indicated to support integrated operations with the individual experiments. The evaluation of payload data management and operations techniques also supports this requirement since the payload support subsystems are a key interface for many LAB experiments.

Recommendations

- No additional study required. The PTC SCS must be capable of executing simulators developed in the SSE. Payload subsystems simulators that are developed for testing flight software development may be modified to support training in the PTC.

Open Issues/Notes

SCS Issue Identification

Issue Title: Fidelity of SS Experiment Simulators

Issue No: T-6 Report Version: 2

Scope of Potential Requirement

The scope of fidelity of experiment simulators can range from total software simulators that provide nominal operations path training on that operation only (e.g. single systems trainers) to fully functional hardware and software simulators that emulate all command and data interactions of an experiment and associated SS subsystems including an extensive library of potential experiment malfunctions. Experiment simulation can also range from simulating only housekeeping/operations data to providing simulation of the experiment science data.

Assumptions

10. PTC experiment simulators will only provide high fidelity simulation of the housekeeping data. Experiment science data will not be dynamically simulated.

11. For loading purposes, all simulations are assume to be done via software. However, the PTC/SCS is assumed to have the hooks and scars to support flight equivalent hardware and software when it is available.

Brief Summary and Rationale

Training Viewpoint

In order to provide adequate payload operations training to the flight crew, the POIC controllers, and payload users, relatively high fidelity simulators of the experiment payloads will be required. These simulators will have to provide realistic data feedbacks in response to experiment control inputs in various operations scenarios. Consolidated operations with other mission payloads will be a significant function of the PTC. The training process will follow a building block approach in which the trainee will advance through levels of increasing task complexity ranging from single experiment nominal operations to consolidated experiment operations malfunction scenarios. The simulator fidelity must support these complex task operations and provide control and data interfaces to the POIC.

SCS Development Viewpoint

The method used to achieve the required fidelity (hardware and software, or a mix) will affect the required size of the SCS. The use of flight equivalent hardware and software will affect the interface requirements to be levied on the SCS.

Operations Evaluations Viewpoint

Experiment simulators of an appropriate fidelity to fully support training should be adequate for all operations evaluation functions. Flight equivalent experiment hardware will be required for testing of maintenance procedures.

Recommendations

o No additional study required. Fidelity of SS experiment simulators will be consistent with the simulators that have been developed for Spacelab. Analysis of the SS design reference mission will determine SCS loading requirements.

Related Issues: A-5

Open Issue/Notes

SCS Issue Identification

Issue Title: Fidelity of SS Experiment/Subsystem Simulator Interfaces

Issue No: T-7 Report Version: 4

Scope of Potential Requirement

The scope of the interface between experiment and subsystem simulators can range from no or limited system/experiment interface to a fully functional two way interface between the subsystem trainers and the experiment simulators.

Assumptions

9. All software subsystem simulators utilized in the PTC will be provided by work package contractors via the SSE. Modifications of these will be required.

Brief Summary and Rationale

Training Viewpoint

The additional emphasis of the PTC to support training for POIC and SSCC indicates a need for greater fidelity of interfaces between experiment and subsystem simulators. Since the MSFC primary training responsibility is to provide integrated training, the simulation of the workstation interfaces and the experiment/system interfaces will be of primary importance.

SCS Development Viewpoint

This will have an impact on conceptual and detailed design, but the requirements for interface are relatively straight forward. Subsystem interface support may be required for high fidelity subsystem simulators developed in the SSTF both for the experiments to respond to subsystem status data and to provide load data that can be reflected in the subsystem simulators in the SSTF. An Interface Control Document will be developed to define the level of interface between the subsystem simulators and the payload simulators.

Operations Evaluations Viewpoint

A key aspect of this issue which requires further evaluation is the amount of interaction with the SS systems by the payload operators in the course of payload operations. If payload operations procedures include significant interactions with the systems, then these systems and their interfaces to the experiments must be simulated to a high degree of fidelity. Additionally, high fidelity subsystem simulator interfaces must be provided to support the evaluation of prototype experiments or support equipment which might interface with the systems.

Recommendations

o No additional study required. This is not a significant issue from the standpoint of the SCS requirements although it may be an issue from the standpoint of the manpower required to develop and implement experiment simulator requirements.

Open Issues/Notes

SCS Issue Identification

Issue Title: Fidelity of SS Experiment Simulator Internal Data Flows

Issue No: T-8 Report Version: 2

Scope of Potential Requirement

Data flow within the PTC between experiments could range from an internal sharing of data within the host system memory to a total emulation of actual data flow services between the experiment and the host data management system.

Assumptions

12. The PTC will utilize DMS Kits that are provided by JSC/WP02.

Brief Summary and Rationale

Training Viewpoint

From a payload operations training viewpoint a simulation of the internal data flows may not be necessary for crew payload operations training as long as the data is available to the trainee in the same format as it would be in the actual operations environment. However, simulation or emulation of certain aspects of the data flow process may be necessary in order to provide training on anomalies or malfunctions relating to the data flow process. For example, for training on experiment operations it would not be necessary to simulate the communications protocol required between the actual SS data management system and the experiment as long as the data was available to the trainee in the same format and access mode as he would have in flight operations environment. However, if the training objective was specific to the data transfer function between the host data management system and the experiments then it would be necessary to simulate the actual protocols and different malfunction scenarios that might result from problems within either the experiment or the data management system.

SCS Development Viewpoint

From a development standpoint, the fidelity of internal data flows is important to determine how experiment data should be simulated and passed to the host system, and fidelity will have an effect on code size, and thus on loading. Data could be simulated in engineering units eliminating the need for data formatting software in the host system, but this might create additional requirements for generating data streams to the POIC consoles if they expect the data in a different format than it is made available to the on-board crew.

Operations Evaluations Viewpoint

Since DMS Kits and some amount of flight software are assumed to be present in the SCS, the required interfaces will be present for the evaluation of different payload data management and operations techniques. The DMS Kits and the ability to run payload software will also support the evaluation of prototype experiments or support equipment. For procedure development and verification, the simulator internal data flows are not considered to be important as long as the simulators produce accurate command responses.

Recommendations

o No additional study required. The utilization of DMS kits or equivalent subsystem simulators provided by JSC requires that internal data flows between the experiments and the host DMS will be the equivalent of flight interfaces.

Open Issues/Notes

We need to determine how many modules and/or workstations the PTC SCS must support.

SCS Issue Identification

Issue Title: Fidelity of SS Experiment Downlink Data and Uplink Command Capability

Issue No: T-9 Report Version: 1

Scope of Potential Requirement

The scope of this issue can range from no downlink telemetry or command uplink capability from/to simulators in the PTC to a full systems simulation of the telemetry/command system. Telemetry data simulation could further range from a static data stream generation to a fully dynamic simulation of all parameters in a data stream. In addition, simulation could be limited to certain data streams such as the Spacelab ECIO data stream without providing simulation of dedicated experiment channel data streams.

Assumptions

13. The PTC will provide for the generation of all experiment data stream formats including dedicated experiment channel data streams. However, the data to fill dedicated experiment data streams will not be dynamic.

14. All data on the payload bus will be simulated at the PTC. The payload bus includes two nodes with 10 megabits of data on each node. The PTC shall also output the data from the systems bus which also contains 10 megabits.

15. Experiment prototype systems will be able to interface to the PTC data stream generator to provide dedicated experiment channel data.

Brief Summary and Rationale

Training Viewpoint

If the PTC is to provide adequate training for the POIC controllers all the command uplink capability that is available to the ground must be simulated. Telemetry data must be simulated to a level of fidelity necessary to support the operations training functions. It may be acceptable to have static data streams for some applications but require dynamic simulations for other parameters. If the data streams are to interface with actual ground data management system software then the data streams must be formatted exactly as the flight data streams. Data acquisition and transfer rates must also be assessed to determine their relationship to the training objectives. Multiplexing of data within the data stream must also be assessed. Generation of the high rate science data streams is desirable but not mandatory for POIC operations position training since generally the high rate data is not processed at the POIC, but is just passed on to the user facilities.

SCS Development Viewpoint

Telemetry data simulators to some level will be an important part of the SCS/PTC. The SCS may be able to obtain and modify telemetry simulation used for test. However, due to the high fidelity required for test, and the different purpose of the simulation, it often is more expensive to understand and modify than build a simple simulation. Developing full fidelity telemetry simulators is a non-trivial amount of development effort.

Operations Evaluations Viewpoint

Full command uplink capability and downlink of accurate command responses are required for the development, evaluation, and verification of ground operations procedures and data bases. A key aspect of this issue is the simulation of the command responses. Accurate responses are required for proper verification of procedures and command data bases. As long as these responses are all included in the experiment housekeeping data (assumed to be dynamically simulated in the SCS), command responses should be accurate. However, if ground command responses are included in the high-rate science data, a dynamic simulation affecting the high-rate data stream could be required.

Recommendations

o No additional study required. The PTC must support full command uplink capability and generation of all payload data stream formats. If the generation of the high rate science data streams is a significant impact to the SCS design, then this requirement may be deleted.

SCS Issue Identification

Issue Title: Fidelity of Element Control Workstation (ECWS)

Issue No: T-10 Report Version: 2

Scope of Potential Requirement

The scope of this requirement can range from a crew interface simulation of the ECWS in which only the on-board crew interface aspects of the ECWS are simulated to a high fidelity to a complete emulation of the flight ECWS by including the appropriate Data Management System (DMS) kits.

Assumptions

16. ECWS simulators will be provided by WP01 contractor.

Brief Summary and Rationale

Training Viewpoint

The important factor concerning the fidelity of the ECWS from a training standpoint is the crew interface items. It is mandatory that data acquisition, presentation, and command input capabilities of the simulated ECWS match the characteristics of the flight system.

SCS Development Viewpoint

The fidelity of the ECWS simulation is important from a development standpoint in terms of ECWS hardware & software. Will special software have to be written to drive the ECWS in the PTC, or will we be able to use the ground equivalent ECWS hardware, and the software that comes with the ground equivalent hardware?

Operations Evaluations Viewpoint

ECWS simulators which are adequate for training should also be adequate for the development and verification of crew procedures. No additional ECWS simulation capabilities should be required since ECWS technology evaluations appear to be outside the role of the PTC. However, if the PTC were to be used for applications such as payload video technology evaluation or prototyping of new payload control devices, flight-like ECWS simulators with flight equivalent interfaces would be required.

Recommendations

o Additional study required. Additional study/analysis is needed to determine the implications on the SCS requirements from the options of utilizing DMS kits in the PTC or simulating the ECWS functions within the host PTC system. One purpose of the additional study will be to determine the approach to the design of the ECWS. In

addition the number of I/O ports required in the SCS for ECWS interface must be determined. This will be determined by the number of modules the PTC must support (i.e. US Lab, ESA, JEM).

Related Issues: A-10

Open Issues/Notes

SCS Issue Identification

Issue Title: Support for Training Multiple Missions Simultaneously

Issue No: T-11 Report Version: 3

Scope of Potential Requirement

The scope of the SCS for the PTC can range from being sized to only support one mission to being required to have 4 separate mission independent systems.

Assumptions

17. The PTC will be required to support full consolidated experiment operations training on 3 SS increment configurations simultaneously (2 U.S. Labs and 1 ESA/JEM) with part task training on individual experiments from 3 other increments (each of the 3 roughly equal to 1/3 of the U.S. Lab in capability).

18. Development and verification efforts must be able to proceed simultaneously with training.

19. For purposes of this study, training and development are assumed to be accomplished on a 40 hours per week day shift basis, with other hours reserved for backup, PM, and overflow work..

20. A backup interface capability will be required between the PTC and the SSTF in order to execute payload simulators in the PTC in support of integrated simulations at the SSTF in some cases where it is not feasible to transport the payload simulator to the SSTF.

Brief Summary and Rationale

Training Viewpoint

The PTC will be required to support both individual experiment operations training and consolidated experiment operations in the integrated flight configurations. PTC training will begin 12 to 15 months prior to a launch. Approximately 6 months will be devoted to individual experiment operations training and 3 months to consolidated training in a consolidated flight configuration element trainer. Assuming that the payload simulators will be transported to the SSTF for the final integrated training exercises, and using the current launch schedule, it can be determined that the PTC must support 3 flight increments involving consolidated training and 3 other increments with individual experiment operations training simultaneously.

SCS Development Viewpoint

This issue will have a major impact on SCS hardware and software. Supporting multiple missions dictates a multi-tasking operating system (O/S) or a

distributed computer/system of some type. Switching hardware and software may be required to allow transitions of training on one mission increment to a different hardware station (full element trainer from part task trainer (PTTs) or between PTTs . The requirements will be fairly straight forward. The effect will be in the different SCS designs that can be developed to meet the requirements.

Operations Evaluations Viewpoint

By providing simultaneous consolidated training on two different increment configurations, the SCS should properly support development and verification of ground and flight crew procedures. Reconfiguration may be required for some procedure testing since the procedure development and training schedules may not coincide. Plans for procedure development should be investigated to determine the correlation with training activities for a given increment and to ensure that the SCS will properly support the procedure development process.

Recommendations

o No additional study required. PTC SCS must support simultaneous consolidated training as assumed above. Development efforts on other increment experiment simulators must be able to proceed while training is in progress.

Open Issues/Notes

SCS Issue Identification

Issue Title: Support to Integrated Simulations with Other NASA Centers

Issue No: T-12 Report Version: 3

Scope of Potential Requirement

The scope of the PTC support to integrated simulations with other NASA centers could range from an isolated PTC that does not interface with other SS simulations in an integrated simulation environment to a full integrated simulations system in which the PTC is an integral part of the SSTF with complete data flow and command control capability from other NASA centers.

Assumptions

20. A backup interface capability will be required between the PTC and the SSTF in order to execute payload simulators in the PTC in support of integrated simulations at the SSTF in some cases where it is not feasible to transport the payload simulator to the SSTF.

Brief Summary and Rationale

Training Viewpoint

The Spacelab experience has demonstrated that integrated mission simulations are perhaps the most valuable training exercise that can be provided to the operations team, both the flight and ground personnel. Payload operations are an integral part of the overall SS operations and must be integrated together in order to provide the payload operators with the necessary insight concerning the payloads relationship to SS subsystem status. Also it is equally important for the subsystem controllers to understand the effects the payloads have on subsystem loads.

SCS Development Viewpoint

The JSC assumption that the SCS simulators will run on a separate host, and interface through messages and data tables opens the possibility of a joint integrated simulation (JIS) through the same interface with the payload simulations running on the SCS. This also will have an impact on the SCS, as requirements to support a JIS imposes additional computing load requirements on SCS. The capability to remotely test a simulation running on the SSTF from the SCS at MSFC would be very handy, even if most of the operation of the payload simulations are done by transporting payload simulations to the SSTF.

Operations Evaluations Viewpoint

Operations evaluation usage of the PTC is not expected to require integration with other NASA centers. These functions will be conducted locally at MSFC.

Recommendations

o No additional study required. It is assumed that the PTC/SSTF interface will be through the SSIS (Space Station Information System).

Notes/Open Issues

Will the SCS need to support training sessions at the SSTF with a payload simulator running on the SCS? The initial assumption was no, but a revisit based on a meeting with JSC has given a current position of yes, for some small percentage of payloads.

SCS Issue Identification

Issue Title: Support for Interoperable (Remote Executions) Simulations

Issue No: T-13 Report Version: 2

Scope of Potential Requirement

The PTC requirement for support of remote operations could range from no remote operation capability of the PTC simulators to a full simulator control and trainee interfaces from remote locations such as PI sites, etc.

Assumptions

21. Training done via remote execution is done on the SCS, or the trainees come to MSFC and train here. Thus, the computing load would be the same, and will be accounted for in the study.

Brief Summary and Rationale

Training Viewpoint

Remote operations capability would make the PTC simulators and training capability more accessible to the trainees by potentially providing the training capability at their home sites. This would reduce time and travel requirements. Factors that must be considered in a remote operations capability include both the simulation control and trainee interface workstations.

SCS Development Viewpoint

Remote execution requirements will affect the SCS hardware design, but not the loading. Remote executions will require special interfaces and either a multi-tasking operation system (O/S), or a distributed computing system.

Operations Evaluations Viewpoint

Remote operations capabilities could allow the PI to perform some procedure prototyping and development at his site. However, it is expected that almost all operations evaluation functions will be performed at the PTC. Operations evaluation functionality is therefore not considered to be a driver on any requirements for remote SCS operations capabilities.

Recommendations

o Additional study required. The affect of remote operations capability on the SCS system design must be determined (e.g. distributed processing requirements). Also, the type of interfaces to remote site workstations must be determined. The potential

operation of experiment simulators located at PI sites remotely operated from the PTC must also be determined.

Related Issues: T-14

Open Issues/Notes

SCS Issue Identification

Issue Title: Requirements for SCS Interface with External Facilities

Issue No: T-14 Report Version: 2

Scope of Potential Requirement

The scope of this requirement could range from the PTC providing a direct training support interface with experiment PI sites, User Operation Facilities (UOFs), Regional Operations Centers (ROCs), and Discipline Operations Centers (DOCs) to the PTC only supporting training at external sites via an interface through the POIC.

Assumptions

5. Any PTC interfaces to UOFs, DOCs, or ROCs will be through the POIC. There will not be any direct data interfaces from the PTC to the UOFs, DOCs, or ROCs.

20. A backup interface capability will be required between the PTC and the SSTF in order to execute payload simulators in the PTC in support of integrated simulations at the SSTF in some cases where it is not feasible to transport the payload simulator to the SSTF.

Brief Summary and Rationale

Training Viewpoint

The PTC will not have any unique training functions or objectives that require a direct interface to any external facilities other than perhaps for remote operations. PTC training support to external operations facilities will be through the POIC.

SCS Development Viewpoint

The simplest development view was our original assumption of no external interfaces except to the POIC. Writing the requirements for interface to the SSTF for a JIS is easy. The affect on the conceptual design could include having a separate computer to support the JIS functions.

Operations Evaluations Viewpoint

The only external facility interface required for operations evaluation functions is to the POIC. This interface will provide for the testing of ground procedures in the POIC. No unique SCS capabilities in excess of those required to support consolidated payload training are required to support this function.

Recommendations

o No additional study required, since there are no unique SCS requirements to train personnel at UOFs, DOCs, or ROCs.

Related Issues: T-2, T-13, A-4

Open Issues/Notes

SCS Issue Identification

Issue Title: Requirements for PTC Payload Video Data

Issue No: T-15 Report Version: 2

Scope of Potential Requirement

The scope of this requirement could range from no video data simulation capability at the PTC to a software controllable video disk system which would provide actual dynamic video data that could be controlled by the PTC simulators.

Assumptions

22. No SCS simulation of EVA or SCS production of other rendered outside attached payload pictures.

Brief Summary and Rationale

Training Viewpoint

For many experiment operations, the video data is the primary source of science data. However, from a training standpoint, what must be considered is the role the video data plays in operational decisions. For many experiments static video data may be acceptable, but for other operations a full dynamic video simulation capability may be required.

SCS Development Viewpoint

Recent advances in graphics hardware and software make video scene generation simulation possible today that would have been impossible or extremely expensive even as short a time ago as 3 years. Simulations can be done now with graphics hardware and software, on graphics hardware and video disk, or graphics hardware and large storage optical disks and CD ROM. Various COTS rapid prototyping tools are maturing that might also support some required video simulations. Details of the requirements in this area will/can result in a wide variety of design solutions, but requirements must be detailed enough to allow designers to determine the proper level of solution required.

Operations Evaluations Viewpoint

A key operations evaluation usage of the PTC could be for the prototyping and evaluation of payload video systems. To support evaluation of video systems intended for final use in the on-board environment, a flight-equivalent payload video system will be required to provide the correct interfaces.

Recommendations

o Additional study required. Additional analysis is required to determine the potential requirements for payload scene data required to support training and the aspects of the potential video data that will affect the SCS requirements. Also any requirements to digitize video data and put it into a data stream must be determined.

Open Issues/Notes

SCS Issue Identification

Issue Title: Requirements for Simulation Parameter Update Rate

Issue No: T-16 Report Version: 3

Scope of Potential Requirement

Simulation parameter update rates can range from once per second to the maximum data acquisition rate of the SS Data Management System. This requirement basically determines the processing time requirement for the simulators that are driving the dynamic parameters.

Assumptions

23. The standard update rate (required to support realistic displays for the trainees in the PTC) for the SCS for dynamic data will be once per second. A subset of the simulator tasks (required to support realistic input by the trainees) will be required to execute at up to 10 Hz rate (e.g. response to hand controller inputs). A rate of 25 Hz may be required for pointing systems.

24. To work with the core subsystem flight equivalent hardware and software, the SCS must work at rates that satisfy this flight equivalent hardware and software.

25. Onboard data storage capability of the DMS will be part of the DMS simulation capability provided by JSC/WP02.

Brief Summary and Rationale

Training Viewpoint

From a crew operations training viewpoint it is only necessary to update the dynamic parameter data at the rate at which the crew can view the data. For example, if the data display system will only update parameter data on a once per second basis it is not necessary for a simulator to execute at any faster rate because once per second is the most granularity that the trainee could ever see in the data. However, for POIC console operations training in which recorded data may be accessed that was acquired at a faster rate it may be necessary to simulate that data acquisition rate if critical data points could have individual sample values and/or trends that occur at the faster acquisition rate.

SCS Development Viewpoint

These rates will have an effect on conceptual design candidate hardware. How often a simulation must run, how large it is, and how many others running at the same speed, and their size, will be big factors in the size and speed of the required SCS computer (s). The more detailed the data and requirements we have, the better will be our selection of hardware.

Operations Evaluations Viewpoint

Since the SCS is assumed to include one or more DMS Kits, it is required to support the data acquisition rates of any flight software utilized. If simulated parameters are updated at the rates they are acquired by flight software, all operations evaluation functions should be adequately supported. For "pure simulators" (those with no flight hardware/software components), parameter update rates which adequately support both flight crew and ground personnel training should also suffice for operations evaluation functions such as procedure development and testing.

Recommendations

o No additional study required. SCS must support execution of simulations at a standard rate of 1 Hz with the capability to also execute some tasks at up to a 25 Hz rate.

Open Issues/Notes

SCS Issue Identification

Issue Title: Requirements for High Rate Data

Issue No: T-17 Report Version: 2

Scope of Potential Requirement

The scope of this requirement can range from no dedicated experiment channel data simulation to a complete simulation of all the science and operations data that is downlinked via dedicated experiment channel data streams. This requirement could also imply a requirement to have high data rate recorders as an integral part of the PTC to record simulated high rate data for downlink at some time after the experiment operation.

Assumptions

13. The PTC will provide for the generation of all experiment data stream formats including dedicated experiment channel data streams. However, the data to fill dedicated experiment data streams will not be dynamic.

Brief Summary and Rationale

Training Viewpoint

In the Spacelab training experience, the simulation of dedicated experiment channel data was not supported by the PCTC. This did not lead to any serious deficiencies in the training environment for the payload crew or for the POCC cadre. However, in many cases dedicated channel data is the only source of experiment operations status and science data that is available to the experiment control teams on the ground. This led to situations during Spacelab training where more data was available to the flight crew in the training environment than was available to the experiment control teams on the ground. The PTC support responsibilities for training the experiment PI teams and to provide an interface for prototype experiment hardware will be the primary driver in determining the need for dedicated channel data simulation.

SCS Development Viewpoint

The rates for generation of all dedicated channel data formats will be a significant factor in communication channel selection. Data will be simulated by data tables, not dynamic simulators. Data may be provided by a PI provided generator.

Operations Evaluations Viewpoint

Accurate responses are required for proper verification of ground procedures and command data bases. As long as these responses are all included in the experiment housekeeping data (assumed to be dynamically simulated in the SCS),

command responses should be accurate. However, if ground command responses are included in the high-rate science data, a dynamic simulation affecting the high-rate data stream could be required to provide effective test capabilities for ground procedures and command data bases. Evaluation of prototype experiments and payload data management technologies may also require a flight equivalent high rate data system to provide the appropriate interfaces.

Recommendations

o No additional study required. The PTC will support the generation of all dedicated channel data formats. However, if this requirement is a significant driver on the SCS design, it may be relaxed.

Open Issues/Notes

SCS Issue Identification

Issue Title: Requirements for Virtual Instruments

Issue No: T-18 Report Version: 2

Scope of Potential Requirement

The scope of this requirement could range from no virtual instrument panel simulation capability in the PTC to a requirement to be able to emulate any type of experiment control and display panel as a virtual instrument in a workstation environment.

Assumptions

26. Virtual instruments are acceptable in the part task experiment simulation workstations, but should not be utilized in the consolidated increment training environment.

Brief Summary and Rationale

Training Viewpoint

Virtual instruments are not desired as training systems for the full flight element configuration training but are probably quite acceptable for individual experiment training utilizing Computer Based Instruction systems and possibly even in the part task trainers for individual experiment operations.

SCS Development Viewpoint

Recent advance in Programmable Entry Panels (PEPs), programmable switches, touch screens, LCD displays, and large screen displays make virtual instruments very attractive as a design solution to SCS requirements where the fidelity does not need to be 100%. It is possible to create a very flexible, generalized, and easily reconfigurable trainer. It seems sensible to tune the SCS fidelity requirements to take advantage of these types of hardware and software.

Operations Evaluations Viewpoint

Virtual instruments have the potential for very valuable usage in the operations evaluation arena. They could be used by experiment developers and other operations personnel to prototype and evaluate potential instrument designs to provide input to the instrument development process. To provide the highest value for this type of evaluation, a capability to rapidly configure prototype simulations to support the virtual instruments is also required. A full experiment prototype could thereby be rapidly constructed and evaluated in advance of the actual experiment development process.

Recommendations

o No additional study required. Virtual instrument simulation capability will be a part of the part task experiment workstations.

Open Issues/Notes

SCS Issue Identification

Issue Title: Requirements for Simplified Simulator Operations Setup and Control

Issue No: T-19 Report Version: 2

Scope of Potential Requirement

The scope of this requirement ranges from a system with a fixed simulation configuration and make-up that is predefined at initial boot of the host computer system to a totally flexible system in which the simulation conductor can define the complement of simulators and the training workstation configurations that he desires for any given training session.

Assumptions

Brief Summary and Rationale

Training Viewpoint

In order to maximize the efficiency of the PTC to support multiple flight increments it is essential that the simulation conductors have the ability to control the contents of any given session. The complement of experiment and subsystem simulators that are to be executed must be selectable by the simulation director and the location/configuration of all workstations involved in the training exercise must be under the simulation directors control.

SCS Development Viewpoint

These types of requirements are very difficult to write so that they are testable. Based on our experience with trainers and operational systems, however, we can write requirements having to do with which function controls what, reconfiguration control and timing, freeze points, restart points, synchronization of functions, and initialization timing and control. Other, more general design goals will have to be included in the function specifications as design goals.

Operations Evaluations Viewpoint

Simplified setup and control functions which fully support training should be adequate for all operations evaluation functions. The operations evaluation functions impose no unique requirements in this area.

Recommendations

o No additional study required. This is an operational design issue but is not a significant driver to the SCS design.

Open Issues/Notes

SCS Issue Identification

Issue Title: Support for Onboard Training

Issue No: T-20 Report Version: 0

Scope of Potential Requirement

The scope of this requirement ranges from no SCS support for onboard training to use of the SCS as a node to support training for crew onboard the Space Station.

Assumptions

27. There are currently no requirements for onboard training levied on the SCS.

Brief Summary and Rationale

Training Viewpoint

It is possible to envision the PTC/SCS as a node to conduct training for crew onboard the Space Station. However, the most likely situation would be to have PTT software that could be transported to the Space Station to be used there for onboard training.

SCS Development Viewpoint

Onboard training would be a factor in development of simulations. The size, and the host machine on which they run might be different. Also, using simulations onboard raises issues of verification, validation, and flight rating the software. Depending on the payload, and where the simulation software runs, software safety issues might also be a factor.

Operations Evaluations Viewpoint

Recommendations

o Additional study required. This is a new issue, and will be tracked as the SCS Study proceeds.

Open Issues/Notes

DEVELOPMENT ISSUES

SCS Issue Identification

Issue Title: Utilization of SSE Capabilities

Issue No: A-1 Report Version: 2

Scope of Potential Requirement

The scope of this requirement could range from having the SCS be fully compatible with the SSE environment to having the SCS be largely independent of the SSE environment.

Assumptions

28. SCS will use SSE capabilities for software development and maintenance.

Brief summary and rationale

Training Viewpoint

The utilization of the SSE capabilities is not important from a payload crew or ground operations personnel training standpoint but may be significant from the standpoint of training the operators, training personnel, and developers who utilize the PTC. Since the SSE provides standard interfaces and capabilities that will be utilized by individuals throughout the payload community involved in the Space Station Program, it is essential that the PTC conform to these same standards.

SCS Development Viewpoint

There is excellent potential for increased productivity in the development area using a proven set of tools to develop the SCS system. There is also good potential for lessening of life cycle maintenance costs using the SSE environment. It makes sense from a compatibility standpoint to utilize SSE. Utilization of SSE will make it easier to transfer/use flight equivalent software. Transporting simulations from the SCS to the SSTF should be eased by using SSE. Common use of SSE CM tools should help inter-center transfer of software and data. SSE will provide CBT tools, and these need to be considered in the conceptual design phase of the SCS Study.

Operations Evaluations Viewpoint

The operations evaluation function imposes no unique requirements relative to the utilization of SSE capabilities.

Recommendations

o No further study required.

Requirements - The SCS system shall follow completely the SS SSE guidelines, and fully utilize the SS SSE capabilities.

Implications - We need to understand the full implications of SSE on the design of the SCS system. As part of the conceptual design, further study will be done of current planned SSE capabilities. Analysis of the development load and training load resulting from other parts of Task 2 activities will be done. This analysis and our experience will be used in the conceptual design phase (Tasks 4 & 5) to help make a recommendation on the possible candidate architectures for the SCS system.

Related Issues: A-13

Open Issues/Notes

The target SCS is an issue, i.e. "Is the actual SCS an SPF -like system?" It is possible to use an SPF to develop the simulation (requirements, design, and code) and then integrate the simulation on a different computer (IT&V), and then run the element trainer simulations on a different computer, the SCS training host computer - this is the current SSTF plan.

SCS Issue Identification

Issue Title: Techniques for Integrating and Maintaining PI-Provided Simulators

Issue No: A-2 Report Version: 3

Scope of Potential Requirement

The scope of this issue ranges from having the PIs develop and test their simulators on the PTC/SCS to allowing the PIs to develop their simulators essentially independently, and integrating them with the PTC/SCS after they are developed and tested.

Assumptions

29. For purposes of loading for the SCS study, all simulations are assumed to be built, integrated, tested, and maintained on the PTC/SCS. Sizing must be done for worst case.

Brief summary and rationale

Training Viewpoint

If experiment simulators are developed by the Principle Investigators and then integrated into the PTC, there could be a significant impact to the task of training the personnel who will conduct the training sessions at the PTC. In order to conduct a training session, the simulation director needs to have a thorough working knowledge of the software being used in the training session. Typically, this knowledge is gained from either a familiarity with the original training and simulator requirements or software development process. If simulators are developed elsewhere and then integrated into the PTC, then another means will have to be developed for MSFC personnel to gain the knowledge necessary to conduct the training sessions. The utilization of computer aided instruction may serve to provide some of the necessary knowledge.

SCS Development Viewpoint

Having the simulators developed on the SCS would be helpful in eliminating many of the integration problems of simulations developed in a different environment. However, having all or most of the simulators developed on the SCS will add a non-trivial amount of computing load on the SCS system and would have a significant impact on the SCS size and configuration. Having simulators developed off site, and then integrated will create its own special set of problems.

This problem can be segmented into: 1) Computer Based Training (CBT), which it would seem logical for the PIs to do, 2) Individual experiment training, which might be handled via a standard part task trainer (PTT) approach done either by PIs or

PTC, and 3) Integrated training, which would have to be a PTC responsibility, but which could use software developed under 2 above as a base.

Off site simulator development problems include successfully communicating interfaces to the off site developers, having unit test and SCS integration occurring in potentially slightly different run time environments, and insuring enough commonality to yield a reasonably short integration period. Independent PI simulator development drives the SCS requirements toward the use of DMS Kits for program standard interfaces.

Operations Evaluations Viewpoint

To support applications such as the evaluation of prototype experiment designs or the use of different payload data management techniques or technologies, the SCS must provide standardized, well-defined interfaces for the integration of externally provided simulators or prototypes. This capability would allow PIs or operations personnel to develop prototype payload simulators, bring them to the PTC, and evaluate different operational concepts for payloads under development. These types of evaluations could then provide feedback to the payload control software requirements analysis and design processes.

Recommendations

o No further study required.

Requirements - The SCS shall provide all the capability needed to develop and maintain all the Space Station Program payload training simulators, including those in the U.S. Lab, the attached payloads, and TBD number of payloads from the international partners.

Implications - This development load will be a big factor in sizing the SCS capability. This will be used in the conceptual design tasks.

Related Issues: A-3, A-11

Open Issues/Notes

What is the difference between making the SCS available to the PIs and having the PTC/SCS people build the simulators? Do we need more terminals, more DMS Kits, or merely a remote capability?

The level of involvement of the international partners needs to be defined. This issue is currently being brought to the Training Working Group.

SCS Issue Identification

Issue Title: Techniques for Supporting Late Changes to Simulators

Issue No: A-3 Report Version: 2

Scope of Potential Requirement

The bounds on this issue are how close to launch you allow changes in the simulators, and also the magnitude of the late changes. Small changes made late may be of little consequence, yet we know large changes made too late in the cycle can have very adverse affects on not only the changed experiment, but other SCS supported simulation activities.

Assumptions

30. Late changes to the simulators are a problem that the PTC/SCS people have to solve.

Brief summary and rationale

Training Viewpoint

The only impact this issue has from a training viewpoint is that if personnel other than the PTC personnel are incorporating late changes into the simulators then some method must be established to keep the training personnel aware of late developments that need to be incorporated into the training scripts.

SCS Development Viewpoint

The lowest cost solution from the development viewpoint is to baseline the requirements before design work on the simulator begins, and never change them. Allow no late changes in the simulators. This of course is not practical, as the real flight hardware and software are often still changing late into the training cycle. Thus, as much accommodation of the late changes in simulators as can be done in some reasonably cost effective manner must be incorporated into the SCS system. This can be done through modular design of the simulators, maximum use of reusable software libraries, maximum use of software productivity tools and helpful software development environments, and use and retention of experienced, sharp software/simulator developers. The key SSE CM capabilities may be useful here too - specifically the change/implementation tracking done using automated SSE tools like APCE. Maximum use of flight software and prototype/engineering hardware could help alleviate some of the adverse affects of late changes.

Operations Evaluations Viewpoint

Techniques for supporting late changes to simulators which fully support training should be adequate for all operations evaluation functions. The operations evaluation functions impose no unique requirements in this area.

Recommendations

o Further Study Required.

Requirements Example - The SCS system shall be capable of incorporating a "minor" change - see below - into an SCS simulator in 5 working days. Incorporate includes design, code, test, and integrate only - documentation time is separate.

Implications - This will have implications on both the requirements and the conceptual design.

Study Definition - Study will be made of state-of-the-art simulation development, emphasizing how quickly changes can be incorporated and tested. Also, other simulator systems with problems and characteristics similar to the PTC/SCS will be contacted and surveyed as to how they deal with this type of problem. We will definitize and categorize changes, i.e. a "minor" change will be defined in terms of scope, and then a requirement can be written as to how quickly a "minor" change is required to be incorporated into SCS simulators. It is important to know the current state-of-the-art so that we produce requirements that can be met. Another approach would be to define several simulation "conceptual frameworks" - e.g. 1) all software simulations with minimal DMS Kits, 2) DMS Kits plus software experiment models, 3) hybrids of DMS Kits, experiment flight equivalent hardware and software models, 4) DMS Kits, flight equivalent experiment hardware and software - and evaluate the framework pros and cons with respect to accommodating late changes by framework category.

Related Issues: A-2, A-11

Open Issues/Notes

SCS Issue Identification

Issue Title: Allowing Software Transportability between SCS and Other Centers

Issue No: A-4 Report Version: 4

Scope of Potential Requirement

Software can be totally transportable to/from the SCS and other SS centers, or not transportable at all between centers.

Assumptions

31. Recent top level agreements that the crew will train together at JSC the final period before launch dictate that the SCS simulations will be transportable to the SSTF.

32. The PTC/SCS people at MSFC will be responsible for maintenance of the payload simulators, including the period when the simulators are used at the SSTF.

33. Integration of the payload simulators into the SSTF will be through a JSC/MSFC agreed upon method.

34. There must be a capability to simulate payloads, if only for simulator maintenance, at the PTC/SCS for the duration of the payload's mission life. Thus, if a payload simulator is both hardware and software, the hardware may be duplicated, virtual panels may be used, or a parallel software simulator may be developed in order to retain the payload simulation capability at the PTC/SCS. The duplicate/substitute simulator may be employed at JSC in place of the original hardware/software simulator at the PTC.

Brief summary and rationale

Training Viewpoint

Having software be transportable to/from other SS centers has many advantages from a training standpoint. It gives great flexibility in the training locations and scheduling when crew training can take place. It allows varying levels of training to be done at different centers by combining simulators developed for different purposes at different centers.

SCS Development Viewpoint

A requirement for transportability would force some level of commonality of hardware and run time environments which might limit the choices for the SCS hardware and software such that the SCS could not accomplish it's primary mission of training payload operators. However, commonality tends to decrease life cycle cross

training and maintenance costs. The SSE should be the common starting point for allowing transportability. Run time environments are covered by our assumption above, but no matter what the assumption, the similar nature of SCS and SSTF will very likely allow selection of a common payload training host computer. Virtual panels may be built for PTC use when the actual hardware is at the JSC/SSTF, or the virtual panels may be sent to JSC for use in the final training period before launch.

Operations Evaluations Viewpoint

To support applications such as the evaluation of prototype experiment designs or the use of different payload data management techniques or technologies, the SCS must provide standardized, well-defined interfaces for the integration of externally provided simulators or prototypes. Operations evaluation functions impose no unique requirements in the area of transportability to other centers except that capabilities to allow this transportability must not preclude the provision of operations evaluation capabilities. For example, SSTF commonality requirements must not preclude capabilities for the evaluation of prototype payload hardware/software.

Recommendations

o No further study required.

Requirements - The SCS developed payload simulators shall be fully transportable to the SSTF facility at JSC. Transportable is defined as being able to run on the SSTF provided payload simulation computer, interface to the SSTF element trainers, and interface with the SSTF systems simulators (including DMS Kits, SSTF system simulations, and flight software).

Implications - Close coordination will be needed on a continuing basis between JSC and MSFC NASA and contractor people as the SSTF and the PTC/SCS are designed and built in order to specify interface agreements and make common design decisions that will support the required transportability.

The SSTF will have available a run time environment that will support SCS developed simulators, e.g the payload computer system shown on the JSC charts will be compatible with the SCS computer.

Related Issues: A-1, T-14

Open Issues/Notes

What about a complex payload simulator that includes a significant amount of hardware? Does this, once installed at the SCS, remain here during the last 3 months of training (done at the SSTF), with a remote operations of this simulator to support the SSTF training, or do we levy a requirement to duplicate the hardware? The current answer is that we should levy requirements to duplicate the hardware.

SCS Issue Identification

Issue Title: Techniques for Integrating Payload Flight Hardware/Software with SCS Simulators

Issue No: A-5 Report Version: 3

Scope of Potential Requirement

The scope of this issue ranges from no integration of flight hardware and software, to full integration and use of flight hardware and software with the SCS simulator.

Assumptions

35. The SCS will support payload flight hardware, i.e. the SCS will have the hardware, software, hooks, and scars to support flight equivalent payload hardware.

Brief summary and rationale

Training Viewpoint

Providing the capability to integrate flight hardware and software into the training environment will potentially enhance the fidelity of the training that can be provided at the PTC. Many experiment operations cannot be learned without hands on experience with either flight or prototype hardware. However, another aspect of flight hardware and software is the restrictions that may apply to its operation in a 1G environment. Malfunction training may also be severely limited by the utilization of flight hardware and software. From a Simulation Computer System standpoint all the proper interfaces that the flight software expects must be provided by the host simulation system. Simulation director control over the system must also be provided to initiate fault insertion and to monitor the trainees response to the instruction being provided. The integration of flight hardware and software into the PTC must be accomplished in a manner to insure that a proper training environment is being provided that will meet the specified payload training objectives.

SCS Development Viewpoint

Building flight hardware/software in parallel with a software simulator means that the software simulator developers will always be pulled by the changes in the flight hardware/software. The requirements for the simulator will always be changing, and it is difficult and more costly to build anything to continually changing requirements. On the other hand, many of these experiment's hardware will not be useable on the ground because there is no vacuum, there is 1G of gravity, etc. However, if the hardware and software are useable on the ground, or there is flight test hardware that is as close to the real flight hardware as possible, to build a realistic simulator very well may require more effort than spending the developers time working interfaces to allow the flight equivalent hardware/software to be used for training. Using the flight test hardware would most likely provide better fidelity, and certainly

would yield more confidence in the accuracy of the training achieved. There is of course the problem of introducing anomalies when using flight equivalent hardware and software. Break out boxes can be used to introduce anomalies.

Operations Evaluations Viewpoint

Using flight hardware and software would give the highest confidence possible for any operations evaluation purposes that the evaluation would be accurate.

Many operations evaluation functions will require the capability to integrate candidate or prototype flight hardware/software with the SCS simulators. Therefore, the SCS must provide flight-equivalent interfaces especially in the areas of data management and communications (including audio and video). The SCS must also provide the capabilities to execute and evaluate prototype flight software which may be supported by prototype software simulations. This capability would allow for the analysis and evaluation of candidate experiment control software designs.

Recommendations

o Further Study Required. Study Definition - We must know enough about the details of what will be required of the SCS to support use of payload flight hardware before we can write the SCS requirements. Some of this knowledge is in house, and some will come from contacting others knowledgeable about SS payloads. The SCS requirements we write must reflect what is needed both in terms of software and hardware required, and hooks and scars required in the SCS system.

Related Issues: T-6,T-8, A-10, A-14

Open Issues/Notes

Do we need DMS Kits in order to support flight equivalent payload hardware? Some payloads will require these, and some will make minimal use of DMS.

SCS Issue Identification

Issue Title: Flexibility for Allowing Advanced Technology Insertion

Issue No: A-6 Report Version: 3

Scope of Potential Requirement

The scope of this issue is to limit the planning for further advances in technology that can be inserted into the SCS to allowing the maximum possible Advanced Technology Insertion. There are two different technologies included in this issue: 1) Technology that will be inserted into the Space Station, and 2) Simulation technology that will need to be inserted into the SCS.

Assumptions

36. Assume the Space Station life cycle is 30 years, but that computers, displays, and other COTS electronic equipment will have to be replaced or upgraded at intervals ranging from 5 to 10 years.

Brief summary and rationale

Training Viewpoint

The flexibility for advanced technology insertion is mandatory from a training standpoint because over the expected life span of the Space Station the experiment operations will continue to evolve and utilize advancing technologies. The PTC SCS must be able to provide the consolidated training environment for these advanced technology applications.

SCS Development Viewpoint

There is a directive from congress, and a NASA Technical Memorandum (87566) entitled "Advancing Automation and Robotics Technology for the Space Station and for the U.S. Economy" that emphasizes the need for the Space Station, since it will have a lifetime of decades, to provide for and aid in the advancement of technology in general, and specifically automation and robotics - which includes artificial intelligence (AI), voice synthesis, voice recognition, natural language, computer vision, image analysis, and teleoperations. This would indicate we should look at ways to provide for insertion of a variety of Space Station advanced technology. Of course, from a development point of view, it is less expensive to limit the amount of time and worry about this issue. The worst case would be to provide very limited capability for technology insertion in the beginning of SCS development, and later in the development cycle decide that technology insertion must be done on a very large scale.

In terms of simulation technology, there has been a great deal of work done in the past 5 years in advancing rapid prototyping, display technology (that makes some

scene generations options open today that were simply not possible just a few years ago), and computer technology. This too indicates that the SCS system should be designed to take advantage of new advances in computer technology, display technology, user interface technology - that may also be inserted into the Station as well as the training facilities - and general advances in simulation technology.

Operations Evaluations Viewpoint

It is apparent that to provide effective training, the PTC must incorporate new technology which affects the payloads on the Space Station. The new technologies may be simulated or flight equivalent hardware/software may be installed in the PTC. The use of DMS Kits and flight equivalent communications systems (e.g. payload video) should provide equivalent flexibility for advanced technology insertion as is provided by the Space Station itself. This flexibility should also provide the appropriate capabilities for evaluation of candidate technologies for possible insertion into the Space Station environment.

Recommendations

o Further Study Required.

Sample Requirements - The SCS shall have the necessary software hooks and hardware scars to be able to accept , with minimum perturbation, advances in Space Station technology, including computers, displays, user interface, AI, and robotics.

The SCS shall have the necessary software hooks and hardware scars to be able to accept, with minimum perturbation, advances in simulation technology, including computers, displays, user interfaces, AI, CAI, and simulation languages.

Study Definition - A projection of all the technologies listed in the above sample requirements will be performed using in house knowledge and other existing projections. The results of this will then be used to write some more realistic and detailed requirements. The results will also be used to guide the conceptual design tasks (tasks 4 & 5), to influence the conceptual design to include features that will ease future technology insertions. As we do our conceptual design, we especially need to locate and identify scars and hooks that are needed.

Open Issues/Notes

SCS Issue Identification

Issue Title: Implications of Simulation Development Cycle

Issue No: A-7 Report Version: 2

Scope of Potential Requirement

There are two aspects to this issue. One is the amount of simulation development done on the SCS computers. Do the PIs develop the simulators on the SCS, or do they all have access to an SPF that will allow them to build simulators. The second aspect is when in the cycle the simulators are built. This will affect whether early experiment prototype simulations are built and used, or if the only goal is to build and use the as-built simulations.

Assumptions

29. For purposes of loading for the SCS study, all simulations are assumed to be built, integrated, tested, and maintained on the PTC/SCS. Sizing must be done for worst case.

Brief summary and rationale

Training Viewpoint

The simulation development cycle has a significant impact on training as the consolidated training program is dependent upon simulators being developed in a timely manner to support the training cycle. In many cases, development and training have to parallel actual experiment development. Simulators have to be available far enough ahead of a launch date to provide adequate training on each experiment. The more complex an experiment's operations are the more time it takes to develop a realistic simulator but it also takes a great deal more time to train the crew members on these complex experiment operations.

SCS Development Viewpoint

This issue has a potentially large affect on the SCS, how big it is, and what it looks like. If all simulations are developed on the SCS, the SCS resources would be significantly larger than if few or none of the simulators are built on the SCS. The phasing and method of building simulators (from experiment prototype simulators to as-built simulators) will also have a potentially large affect on the SCS requirements. If experiment prototype simulators are built, this will affect the load on the SCS. Perhaps more importantly, if COTS rapid prototyping is used, this might lessen the load on the SCS, or require different hardware to be available as part of the SCS.

Operations Evaluations Viewpoint

There are no unique operations evaluations considerations in the main training simulation development cycle. However, a simulation rapid prototyping capability is required for use in evaluating new payload control concepts, user interface techniques, etc. For example, this capability would allow operations personnel to construct prototype experiment displays and control software and use a simulation built with rapid prototyping tools to evaluate the operation of the experiment. Succeeding tests could then be run against the same simulation to compare different user interface techniques.

Recommendations

o Further Study Required. Study Definition - We will continue to define the simulator development load, expanding on what we have already done and discussed. This will be combined with the assessment of the training load, also ongoing, with the result that we will have a good idea of the total load that the SCS must support.

Related Issues: A-2

Open Issues/Notes

Separate development and simulator IT&V facilities may be required like the SSTF.

SCS Issue Identification

Issue Title: Sizing Growth Potential in Capability/Capacity

Issue No: A-8 Report Version: 3

Scope of Potential Requirement

The scope of this issue is to have a small reserve in capacity/capability to having a large reserve in capability/capacity.

Assumptions

36. Assume the Space Station life cycle is 30 years, but that computers, displays, and other COTS electronic equipment will have to be replaced or upgraded at intervals ranging from 5 to 10 years.

Brief summary and rationale

Training Viewpoint

Any system upgrades that are incorporated into the SCS must be accomplished in a manner that does not impact ongoing training activities. Since many experiments may re-fly several times on the Space Station, it is important that the experiment simulators be re-usable and available for training on later missions. If system enhancements and modifications are made, then the already developed software simulators and interfaces to existing experiment hardware must be compatible to continue to support training. Otherwise, the maintenance activity for experiment simulators that were developed under previous versions of the SCS will be significantly increased and could affect the availability of a simulator to support planned training schedules.

SCS Development Viewpoint

The less reserve capacity in a system, as long as the system is fully functional, the less the system costs initially. The greater the uncertainty in the requirements and the data sizes and scenarios used to generate the requirements, the greater should be the requirement for reserve growth potential capability/capacity. Also, the longer the expected lifetime of a system, the greater the need for larger margins in capability/capacity.

This issue also relates to the ease of growth, i.e. replacement of hardware without modifying applications software.

Operations Evaluations Viewpoint

The operations evaluation function imposes no unique requirements in the area of growth potential in capability/capacity.

Recommendations

o Further Study Required. In conjunction with the study on training load and development load on the SCS, we need to define the SCS capacity in terms of the number of developers supported, the number of different payloads the developers are working on, the complexity of each of the payloads, the number of students being trained, the number of different increments supported at one time, and the number of instructors. These can then be turned into SCS requirements. Also, they will be key in the concept definition tasks. We also need to define the computer parameters that will define growth potential. It also would be useful during the conceptual design task to plot growth vs. cost.

Open Issues/Notes

SCS Issue Identification

Issue Title: Defining Telemetry Data Format and Calibration

Issue No: A-9 Report Version: 2

Scope of Potential Requirement

The scope of this issue is to have the SCS output realistic telemetry data in packet format, to having the SCS bypass the POIC front end, and put data into the POIC in engineering units that can go right into the POIC.

Assumptions

Brief summary and rationale

Training Viewpoint

The simulation fidelity requirements for formatting output data into the proper telemetry formats relates to the functions of the personnel that are using the simulator system for training. In the Spacelab training environment, the initial object of the simulators was to train the payload in on-board experiment operations. For this reason, it was only important to provide data in the engineering unit format that was available to the on-board crew. Uncalibrated raw data formats would have little meaning to the crew members. For the Space Station training it will be equally important to train ground personnel who will be handling data in flight formats.

SCS Development Viewpoint

Not having to deal with telemetry data in packet form is obviously a cost savings, unless the DMS Kits provide this processing as part of their services. However, if integrated simulations with JSC or other SS Centers are to be done remotely, this could be very difficult unless the SCS can produce telemetry with packets in the real format. Building the SCS without the capability to produce telemetry data in the real form with packets will place a limitation on the future use of the SCS. Also, building the ability to produce telemetry in the proper format may prove cost effective in the long run if there are uses, since the packet form should ensure compatibility with a broad range of users.

Operations Evaluations Viewpoint

For development and testing of ground procedures and data bases, the SCS must provide telemetry data to the POIC. This data must provide realistic responses to ground commands but the actual format of the telemetry data transmitted from the SCS is not driven by any operations evaluation requirements.

Recommendations

o No further study required. However, for the current purposes of the SCS Study, this issue will be considered open. The potential for gains in flexibility and capability may outweigh the cost of this currently "not needed" capability. This will be looked at in the conceptual design phase.

Related Issues: A-5. If part of a simulator produces real telemetry, we will need realistic telemetry data.

Open Issues/Notes

SCS Issue Identification

Issue Title: Fidelity of DMS Interface

Issue No: A-10 Report Version: 3

Scope of Potential Requirement

The scope of this issue ranges from having a limited hardware/software simulation to having a DMS Kit.

Assumptions

8. The PTC will not be responsible for any subsystems training. However, the PTC will utilize minimum subsystem interfaces as necessary to support payload training.

12. The PTC will utilize DMS Kits that are provided by JSC/WP02.

37. A host-based DMS functional simulation (FSIM) to be provided by SSE will NOT run in real time. Thus, FSIM is assumed to be of minimal utility in the SCS.

Brief summary and rationale

Training Viewpoint

The DMS will be a major interface device for payload crew control of payload experiment operations. The fidelity of this interface must be near flight type in order to provide an adequate training environment for the payload crew. The characteristics of the keyboard and terminal must be flight like in order for the trainee to gain the proper familiarity with the control and monitor interface.

SCS Development Viewpoint

Some systems interaction will be necessary to have a realistic enough simulator for payloads. The level of interaction between the experiments and the system is a large factor in the requirement for a high fidelity DMS simulation. It appears that the level of interaction between experiments and the DMS may be fairly high, and this would indicate that a fairly high fidelity simulator will be required, or the use of real DMS hardware/software will be required.

Operations Evaluations Viewpoint

A flight-like DMS interface is required for the evaluation of prototype experiments and prototype experiment control software. Both the physical DMS interfaces and software interfaces are required. The physical interfaces (FDDI and local busses) will be used for the connection of prototype experiments or prospective payload data management hardware. The software interfaces (Operating System,

CUI, OMA, and DMS services) will be used to provide a flight-like environment for the execution of prototype user interfaces and payload control software.

Recommendations

o Study required. This study is associated with the one for A-5 - Techniques for integrating flight hardware and software with the SCS. The fidelity of the DMS interface will affect the SCS ability to interface with flight hardware and software.

Sample requirement - The SCS will interface to the DMS to the level sufficient to support payload training.

Related Issues: T-8,T-10, A-5, A-14

Open Issues/Notes

A key part of this issue is the possible requirement to run flight (experiment) software in the SCS. The use of prototype hardware may require DMS Kits.

The requirement to transport SCS payload simulators to the SSTF also affects the way in which the SCS simulates the DMS interface.

SCS Issue Identification

Issue Title: Definition of No Single Point of Failure

Issue No: A-11 Report Version: 4

Scope of Potential Requirement

This issue involves the level of need for backup for every SCS component, and the consequent cost of not having a backup for every component, i.e. no single point of failure.

Assumptions

Brief summary and rationale

Training Viewpoint

No single points of failure is an extremely important issue from the training viewpoint. It is important that the PTC be able to conduct its training programs without significant impact due to system hardware failures. In most cases, the schedules of the personnel involved in training will be booked solid far in advance which will make it next to impossible to reschedule a training session that has to be canceled due to a facility problem. Consolidated training exercises that involve experiment team representatives with the crew and ground operations cadre may involve travel for a large number of the participants that cannot be rescheduled without significant costs to the program.

SCS Development Viewpoint

The basic issue here is one of cost of backup hardware vs. cost of lost training time for a system which has many single points of failures. All time critical computer systems (like banks, communications systems, military systems with 24 hour per day 365 days per year requirements) have backups to minimize down time. Given fixed launch dates for SS crews, and critical training schedules, having a no single point of failure in the SCS/PTC training system could well be a needed system requirement.

The hardware implications of no single point of failure are fairly straight forward - there is a backup hardware for every piece of SCS hardware. The software issues are a bit more complex: What is the fail over time? Is there a requirement to maintain some history data as part of fail over? How much history must be kept? How to re-synchronize after fail over? If failure occurs while messages are on the line, how do you decide if they need to be retransmitted?

A different approach would be to specify availability, reliability, MTTR, and MTBF requirements for the SCS. This might prove to be a more cost effective method of minimizing lost crew training time.

Operations Evaluations Viewpoint

The operations evaluation function imposes no unique requirements in the area of the definition of no single point of failure.

Recommendations

o Study required. Related to the A-3 study of other simulators we will investigate their availability and time to recovery requirements. This will be the approach to writing SCS failure requirements, i.e. there will be a requirement for system availability, and a requirement for recovery time. There are some systems that are operational that can be used to obtain achievable and needed availability requirements

Related Issues: A-3, A-2

Open Issues/Notes

SCS Issue Identification

Issue Title: Requirements for Interfaces with SSIS and SOAN

Issue No: A-12 Report Version: 2

Scope of Potential Requirement

The scope of this issue ranges from having no interface with SSIS (Space Station Information System) and SOAN (Science Operation and Analysis Network), to being able to send simulated experiment data from the SCS to the SSIS and SOAN.

Assumptions

38. The current assumption is that all interfaces to SSIS and SOAN will be through the POIC. Thus, the SCS need only worry about the proper interface to the POIC, and the POIC will solve further external interface problems.

Brief summary and rationale

Training Viewpoint

The only impact this issue has from the training viewpoint is if the PTC has the responsibility to provide training for either crew or ground operations personnel in operational functions that are unique to the SSIS or SOAN interface.

SCS Development Viewpoint

Having an interface to SSIS and SOAN will increase the size and complexity of the SCS software. It might also have some effect on the SCS hardware, depending on what is required to interface with SSIS and SOAN.

Operations Evaluations Viewpoint

Operations evaluation usage of the PTC is expected to be conducted locally at MSFC. Therefore, the operations evaluation function imposes no unique requirements for interfaces with SOAN and SSIS except for the POIC interface discussed in other issues.

Recommendations

o No study required.

Requirement - The SCS shall interface with and be fully capable of using the SSIS network.

Open Issues/Notes

This has implications on the actual design of the SCS, but may not have much of an effect on a top level concept definition.

SCS Issue Identification

Issue Title: Requirements for Configuration Management of Simulation Software

Issue No: A-13 Report Version: 3

Scope of Potential Requirement

The scope of this issue ranges from having minimal configuration management of simulation software to having full and complete configuration management of the simulation software, just like will be done for the flight software.

Assumptions

Brief summary and rationale

Training Viewpoint

Configuration management is perhaps one of the most critical issues from the training viewpoint. It is necessary that the training programs will have to be repeated many times for different crews and operations personnel. An adequate configuration management system is imperative so that the training conductors will always know what version of a simulator is available to them to use for each particular training exercise. To be effective the configuration management system should be largely transparent to the users of the system.

SCS Development Viewpoint

If SSE is utilized to a large extent, there are enough tools for configuration management (CM), that not much other effort will likely be needed in the CM area for SCS. If SCS does not utilize SSE as much, then some attention must be paid to developing a cost effective CM plan. Whatever tools are used, a sound, basic CM plan and set of tools must be part of the SCS/PTC system to reduce to near zero training time lost to CM problems.

An ideal CM system would automate much of the work and provide traceability such that it would be easy to see, when something changed, what other items would be affected.

Operations Evaluations Viewpoint

The operations evaluation function imposes no unique requirements for configuration management of simulation software.

Recommendations

o Study required. Configuration of the computer hardware and displays will be accomplished operationally, as is done at most computer facilities. We will look at the SSE tools, and write requirements based on the tools, and experience with the PCTC.

Related Issues: A-1

Open Issues/Notes

For the PTC, there is the issue of hardware CM to control the configuration of the panels, switches, etc.

SCS Issue Identification

Issue Title: Definition of GSE-Provided Services

Issue No: A-14 Report Version: 2

Scope of Potential Requirement

The scope of this issue is for all training to be done with simulators, i.e. no GSE provided services, to provisions for all payload related SS services.

Assumptions

35. The SCS will support payload flight hardware, i.e. the SCS will have the hardware, software, hooks, and scars to support flight equivalent payload hardware.

Brief summary and rationale

Training Viewpoint

From the training viewpoint this issue is basically the same as issue A-5.

SCS Development Viewpoint

Flight equivalent experiment hardware will require the SCS to be able to provide a relatively full set of SS services. Spacelab PCU/ATE experience indicates a significant impact on potential SCS functional requirements. These types of interfaces will increase the cost of both SCS hardware and software. The best thing that can be done to reduce costs is to identify requirements for these types of services as early in the development cycle as possible.

Operations Evaluations Viewpoint

Some GSE-provided services (e.g. power, thermal, fluids) may be required for some operations evaluation functions involving flight-like or prototype experiments. However, these are the same GSE requirements that are imposed for the use of flight equivalent hardware for training. Further evaluations should be performed to define firm requirements in this area.

Recommendations

o Study required. We will determine and categorize the types of services needed by the envisioned payload manifest. This will allow us to assess the impact on SCS, and write the appropriate requirements for SCS to support this.

Related Issues: A-5, A-10

Open Issues/Notes

SCS Study Issues Assumptions

1. Primary responsibility of the PTC is to provide payload operations training including both nominal and contingency operations for flight and ground personnel.

2. Payload operations training will include experiment training, payload unique operations support systems training , and payload unique subsystems training.

3. The PTC/SCS will support all manned payload training for all payloads, including US Lab, Attached Payloads, ESA, and JEM.

4. ESC training is assumed to not be a responsibility of the PTC. No unique interface between the ESC and the SCS is required, nor will the SCS simulators require any unique capabilities related to ESC training. The only support of the SCS to ESC training will be via the POIC during consolidated and/or integrated simulations.

5. Any PTC interfaces to UOFs, DOCs, or ROCs will be through the POIC. There will not be any direct data interfaces from the PTC to the UOFs, DOCs, or ROCs.

6. The POIC can support the processing of real time or simulated data streams simultaneously. This means the POIC can support training using simulated data from the PTC simultaneous with on going real time operations.

7. The OMS software functions will be provided as part of the DMS Kits. Therefore no special simulator development will be required for OMS training.

8. The PTC will not be responsible for any subsystems training. However, the PTC will utilize minimum subsystem interfaces as necessary to support payload training.

9. All software subsystem simulators utilized in the PTC will be provided by work package contractors via the SSE. Modifications of these will be required.

10. PTC experiment simulators will only provide high fidelity simulation of the housekeeping data. Experiment science data will not be dynamically simulated.

11. For loading purposes, all simulations are assume to be done via software. However, the PTC/SCS is assumed to have the hooks and scars to support flight equivalent hardware and software when it is available.

12. The PTC will utilize DMS Kits that are provided by JSC/WP02.

13. The PTC will provide for the generation of all experiment data stream formats including dedicated experiment channel data streams. However, the data to fill dedicated experiment data streams will not be dynamic.

14. All data on the payload bus will be simulated at the PTC. The payload bus includes two nodes with 10 megabits of data on each node. The PTC shall also output the data from the systems bus which also contains 10 megabits.

15. Experiment prototype systems will be able to interface to the PTC data stream generator to provide dedicated experiment channel data.

16. ECWS simulators will be provided by WP01 contractor.

17. The PTC will be required to support full consolidated experiment operations training on 3 SS increment configurations simultaneously (2 U.S. Labs and 1 ESA/JEM) with part task training on individual experiments from 3 other increments (each of the 3 roughly equal to 1/3 of the U.S. Lab in capability).

18. Development and verification efforts must be able to proceed simultaneously with training.

19. For purposes of this study, training and development are assumed to be accomplished on a 40 hours per week day shift basis, with other hours reserved for backup, PM, and overflow work..

20. A backup interface capability will be required between the PTC and the SSTF in order to execute payload simulators in the PTC in support of integrated simulations at the SSTF in some cases where it is not feasible to transport the payload simulator to the SSTF.

21. Training done via remote execution is done on the SCS, or the trainees come to MSFC and train here. Thus, the computing load would be the same, and will be accounted for in the study.

22. No SCS simulation of EVA or SCS production of other rendered outside attached payload pictures.

23. The standard update rate (required to support realistic displays for the trainees in the PTC) for the SCS for dynamic data will be once per second. A subset of the simulator tasks (required to support realistic input by the trainees) will be required to execute at up to 10 Hz rate (e.g. response to hand controller inputs). A rate of 25 Hz may be required for pointing systems.

24. To work with the core subsystem flight equivalent hardware and software, the SCS must work at rates that satisfy this flight equivalent hardware and software.

25. Onboard data storage capability of the DMS will be part of the DMS simulation capability provided by JSC/WP02.

26. Virtual instruments are acceptable in the part task experiment simulation workstations, but may not be good enough for use in the consolidated increment training environment.

27. There are currently no requirements for onboard training levied on the SCS.

28. SCS will use SSE capabilities for software development and maintenance.

29. For purposes of loading for the SCS study, all simulations are assumed to be built, integrated, tested, and maintained on the PTC/SCS. Sizing must be done for worst case.

30. Late changes to the simulators are a problem that the PTC/SCS people have to solve.

31. Recent top level agreements that the crew will train together at JSC the final period before launch dictate that the SCS simulations will be transportable to the SSTF.

32. The PTC/SCS people at MSFC will be responsible for maintenance of the payload simulators, including the period when the simulators are used at the SSTF.

33. Integration of the payload simulators into the SSTF will be through a JSC/MSFC agreed upon method.

34. There must be a capability to simulate payloads, if only for simulator maintenance, at the PTC/SCS for the duration of the payload's mission life. Thus, if a payload simulator is both hardware and software, the hardware may be duplicated, virtual panels may be used, or a parallel software simulator may be developed in order to retain the payload simulation capability at the PTC/SCS. The duplicate/substitute simulator may be employed at JSC in place of the original hardware/software simulator at the PTC.

35. The SCS will support payload flight hardware, i.e. the SCS will have the hardware, software, hooks, and scars to support flight equivalent payload hardware.

36. Assume the Space Station life cycle is 30 years, but that computers, displays, and other COTS electronic equipment will have to be replaced or upgraded at intervals ranging from 5 to 10 years.

37. A host-based DMS functional simulation (FSIM) to be provided by SSE will NOT run in real time. Thus, FSIM is assumed to be of minimal utility in the SCS.

38. The current assumption is that all interfaces to SSIS and SOAN will be through the POIC. Thus, the SCS need only worry about the proper interface to the POIC, and the POIC will solve further external interface problems.